D2

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 March 2002 (28.03.2002)

PCT

(10) International Publication Number
WO 02/25695 A2

(51) International Patent Classification⁷: H01J 37/32

(21) International Application Number: PCT/US01/28318

(22) International Filing Date:
12 September 2001 (12.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/233,623 18 September 2000 (18.09.2000) US

(71) Applicant *(for all designated States except US)*: TOKYO ELECTRON LIMITED [JP/JP]; TBS Broadcast Center, 3-6 Akasaka 5-chome, Minato-ky, Tokyo 107 (JP).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: JOHNSON, Wayne, L. [US/US]; 13658 S. 32nd Street, Phoenix, AZ 85044 (US).

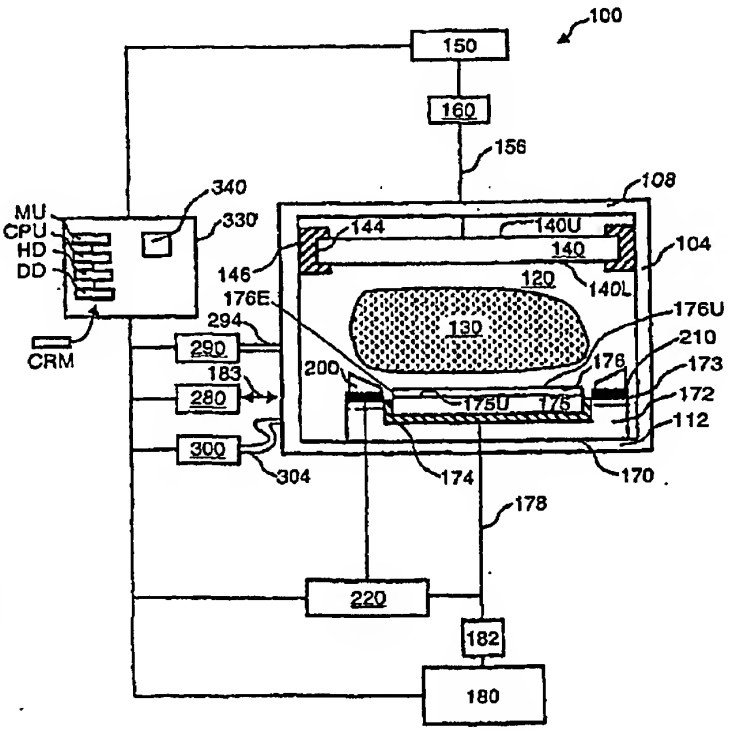
(74) Agents: LAZAR, Dale, S. et al.; Pillsbury Winthrop LLP, 1600 Tysons Boulevard, McLean, VA 22102 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF,

[Continued on next page]

(54) Title: TUNABLE FOCUS RING FOR PLASMA PROCESSING



(57) Abstract: A focus ring (200) and related assembly for a plasma reactor system (100, 400) for processing a workpiece (176) having an outer edge and an upper surface. The assembly has a focus ring support surface (173) arranged around the workpiece perimeter and a ring electrode (210) arranged atop the focus ring support surface. An insulating focus ring (200) is arranged atop the ring electrode. In one embodiment, a first RF power supply (1890) is electrically connected to the focus ring electrode and a tuning network (220) is arranged between the first RF power supply and the ring electrode. Methods of forming a plasma (130) and processing a workpiece in an optimized way, as well as a plasma reactor system for accomplishing the same, are also disclosed.

WO 02/25695 A2

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to plasma processing, and in particular relates to apparatus for and methods of improving plasma processing uniformity.

With reference to FIG. 1A, plasma reactor system 100 comprises a reactor chamber with sidewalls 104, an upper wall 108 and a lower wall 112 defining an interior region 120 capable of supporting a plasma 130. Arranged within interior region 120 near upper wall 108 is an electrode 140 having an upper surface 140U, a lower surface 140L and a periphery 144. Electrode 140 is referred to as the "plasma electrode." Insulators 146 are arranged between electrode periphery 144 and sidewalls 104 to electrically isolate electrode 140 from the chamber. System 100 further includes a RF power supply 150 electrically connected to upper surface 140U of electrode 140 via a RF feed line 156 that passes through upper wall 108. A match network 160 is preferably arranged in RF feed line 156 between electrode 140 and RF power supply 150. Match network 160 is tuned to provide the best match to the load presented by plasma 130 formed within interior region 120 so as to optimize power transfer to the plasma.

With reference also to FIG. 1B, reactor system 100 further includes a workpiece support member 170 arranged adjacent lower wall 112 opposite electrode 140. Workpiece support member 170 includes a base 172 having an upper annular focus ring support surface 173, an insulating region 174 and a lower electrode 175 having an upper surface 175U capable of supporting a workpiece 176, such as a wafer, to be processed (e.g., etched or coated) by means of plasma 130. Workpiece 176 has an outer edge 176E and an upper surface 176U. Insulating region 174 is filled with an insulating material such as ceramic or quartz, and electrically insulates base 172 from lower electrode

175. Electrically connected to lower electrode 175 via a RF feed line 178 is a lower electrode RF power supply 180 for biasing the lower electrode. Preferably included between RF power supply 180 and lower electrode 175 in RF feed line 178 is a match network 182.

With continuing reference to FIGs. 1A and 1B, also included in plasma reactor 100 is an annular focus ring 200 arranged atop surface 173 of workpiece support member base 172. Focus ring 200 is an annular ring of nonconducting material surrounding but electrically isolated from workpiece 176. Focus ring 200 is preferably made from quartz, but may also be made of silicon, silicon carbide, alumina, etc. or any of many insulating materials or insulating material compositions or semiconductors. Focus ring 200 may be made with any one of a number of cross-sectional profiles, such as the linear radially increasing thickness profile shown in FIGS. 1A and 1B or any of the exemplary profiles of FIGS. 2A –2D. Alternatively, the focus ring profile need not be uniform around the entire periphery of the focus ring. Such a variable profile focus ring can provide differential etching and edge-effect compensation. A peripherally variable profile focus ring is useful to compensate for azimuthal asymmetries introduced by other aspects of the reactor design, i.e., field/plasma asymmetries.

Arranged between surface 173 and focus ring 200 is a ring electrode 210 and an insulating layer 212, wherein the insulating layer electrically isolates the ring electrode from conductive base 172. Base 172 and chamber walls 104, 108 and 112 are preferably connected to ground. Ring electrode 210 is electrically connected to a tuning network 220 via inner conductor 213 of a transmission line 214. Tuning network 220 is electrically connected to lower electrode RF power supply 180 via a match network 182. The combination of focus ring 200, ring electrode 210, tuning network 220, match network 182 and RF power supply 180 constitute a focus ring assembly within system 100.

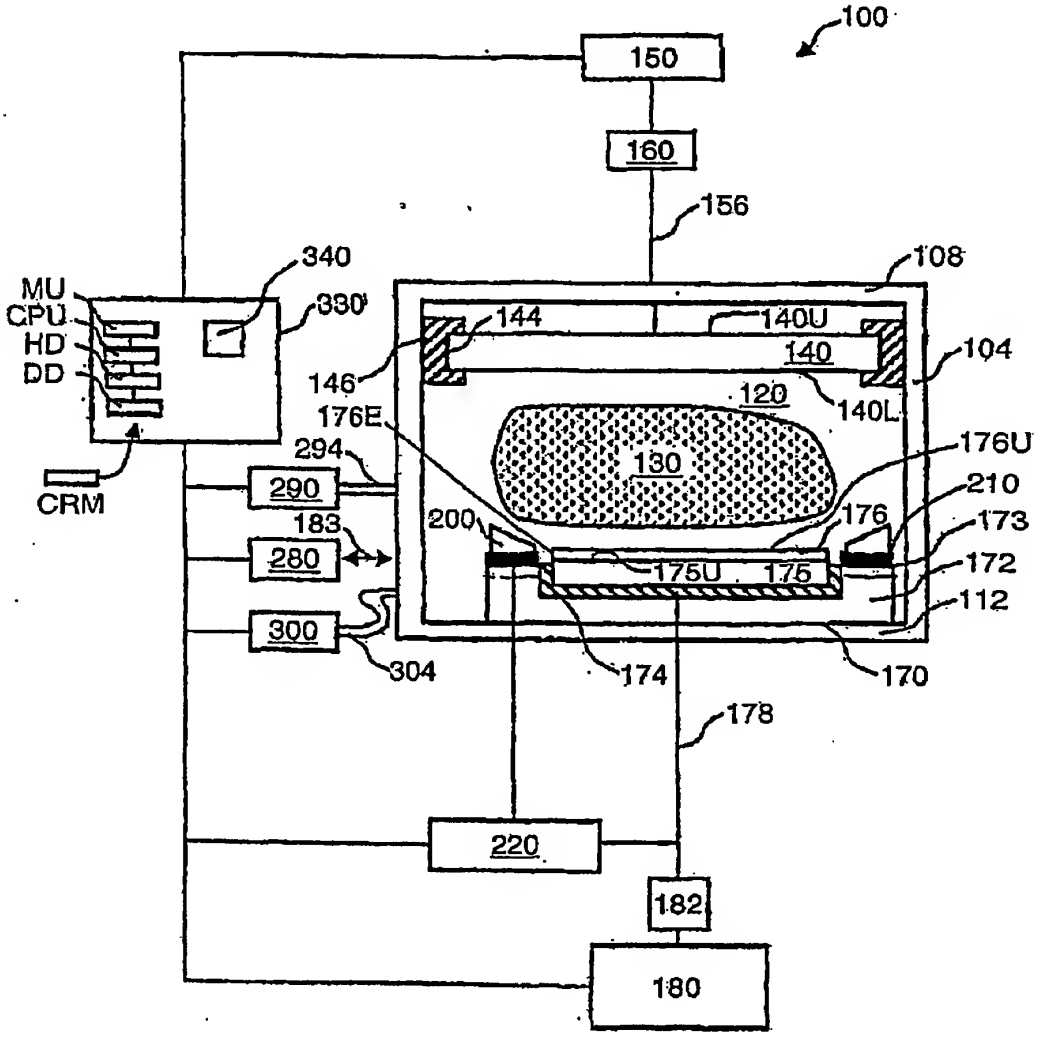

100
150
160
156
340
108
MU
CPU
HD
DD
330
144
140U
140
104
146
120
140L
176E
130
176U
294
290
210
CRM
183
200
176
173
280
175U
175
172
300
112
304
174
170
178
220
182
180

FIG. 1A